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VOL. XIV JULY, 1920 No. 6

THE ORIGIN OF SPECTRA.*

BY H. H. PLASKETT

Since a definite knowledge of the structure of the atom has been acquired it has been possible to gain a clearer idea of the mechanism by which spectra are produced. In particular, the last eight years have witnessed remarkable progress in this branch of knowledge. The pioneer work of Nicholson on the origin of celestial spectra has been extended to certain terrestrial elements, and there has been a consequent stimulation to spectroscopic research.

It is proposed to give here a brief account of the salient points in our knowledge of the origin of spectra. Before considering the theories of Nicholson and Bohr, a summary of modern ideas on atomic structure will be given as well as a review of certain facts with regard to line spectra, which are of critical importance in a study of their origin.

STRUCTURE OF THE ATOM

1. The discovery of radium by the Curies and the subsequent study of radio-active processes have shown that atoms are no longer merely a convenient fiction for giving a picture of chemical processes, but that they actually exist. Recent work has further indicated that they are not the simple elastic spheres of the kinetic theory, but possess a very definite structure.

The discovery by Sir J. J. Thomson[1] of negatively electrified particles in cathode-ray tubes, travelling with velocities comparable

*A paper given before the Seminar, Dominion Astrophysical Observatory.

with that of light, was the first clue to the structure of the atom. The ratio of their charge to mass e/m was determined by their deflections under an electrostatic and magnetic field. The researches of C. T. R. Wilson,[2] which showed that the condensation of water vapour took place on ions (positively and negatively electrified particles) in a gas, furnished a means of determining the charge, e, carried by these particles. From numerous experiments by this and other methods it has been shown that $e = 4.7 \times 10^{-10}$ electrostatic units. The value of e/m is 1.77×10^{7} electro-magnetic units per gram, which gives for m, 8.99×10^{-28} gm. The fact, that in all experiments the charge e or some integral multiple of it always appears, shows that it is the indivisible unit of electricity. These negatively electrified particles bearing such a charge are called electrons.

All experimental evidence points to the fact that the mass of the electron is electrical. For it was earlier shown by Sir J. J. Thomson,[3] that the energy of a sphere of mass m, radius a and charge e, moving with a velocity v, was given by $\frac{1}{2}(m + 2e^2/3a)v^2$. Such a sphere will act as if its mass had been increased by an amount $2e^2/3a$. This extra, or electrical, mass is due to the magnetic field set up by the sphere, when a change in its motion takes place. It, therefore, varies with the velocity. It is clear, then, that if the mass of the electron is totally mechanical the value of e/m will not vary with the velocity. If the mass is totally electrical Lorentz has shown that it will obey a formula

$$\frac{\text{electrical mass } m \text{ at velocity } v}{\text{electrical mass } m \text{ for small velocities}} = \sqrt{1 - \beta^2}$$

where β is the ratio of the velocity of the electron to the velocity of light. If the mass is partly electrical and partly mechanical, then the rate of increase of mass will be less than that given by the above formula. The maximum velocity attainable in a vacuum tube is one-third that of light. The increase of mass to be expected under these conditions is only 5%. It has, however, been shown that the β particles emitted by radium are electrons travelling with velocities within 4% of light. Using these β particles, Kaufmann[4] has obtained a variation in e/m such as given by the formula of Lorentz. His results also fit a formula derived from relativity. It is, there-

fore, concluded that the mass of the electron is entirely electrical. Since the electrical mass is given by $2e^2/3a$ it is possible to calculate a the radius of the electron. It is 1.87×10^{-13} cm.

2. These electrons are a constituent of all atoms. This is clearly shown by their emission from radio-active matter, from metals under the influence of ultra-violet light (photo-electric effect), and from hot bodies, and also their appearance in a gas when exposed to X-rays. In order to determine the number of these electrons per atom Crowther[5] investigated the scattering of β rays after passing through thin sheets of matter. Each electron encountered will repel the β ray, which is, of course, also an electron, with a force varying inversely as the square of the distance. For a given deflection it is possible to deduce, from the theory of probability, the probable number of such encounters suffered by the β ray in passing through the thin sheet. As the number of atoms in a given thickness of the sheet can readily be determined, it is possible to deduce the number of electrons per atom. The interpretation of Crowther's results depends, however, upon the arrangement of the positive charge in the atom. If it be assumed that it is distributed uniformly over a sphere co-extensive with the atom, then the number of electrons is three times the atomic weight. If, however, the positive charge forms a nucleus at the centre of the atom, then the number of electrons is approximately one-half the atomic weight of the element. If a beam of X-rays (light whose wave length is of the order of 10^{-7} cm.) passes through a thin sheet of matter, the electrons within the atom will act as sources of secondary radiation. From the intensity of this secondary radiation Barkla[6] deduced that the number of electrons per atom was approximately one-half the atomic weight. This result is independent of any assumption as to the nature of the positive part of the atom, and indicates, in combination with Crowther's work, the probability that the positive part is concentrated in a nucleus at the centre of the atom.

Since the normal atom is electrically neutral the charge carried by the positive part of the atom, expressed in terms of e, will be equal to the number of electrons in the atom. Rutherford,[7] from the scattering of α rays in passing through thin sheets of matter, has determined the magnitude of this charge carried by

the positive part of the atom. A long series of investigations[5] had previously shown that α rays, ejected in radio-active disintegration, carry a charge of $+2e$, and are helium atoms. Using Radium C as a source of these high-velocity helium atoms, Rutherford found that, though about 1 in 8,000 were turned through a right angle, the majority passed through sheets of thickness 100-1000 atoms almost undeflected. This showed a very open-work structure for the atom and, in conjunction with Barkla and Crowther's results, indicated rather clearly that the positive part of the atom must be concentrated in a nucleus in the centre of the atomic system. In fact it is only on this assumption that Rutherford's numerical results can be explained. The α particles will then describe hyperbolic orbits on a near encounter with the nucleus of an atom, and the number eventually scattered through any angle ϕ will be directly proportional to $\mathrm{cosec}^4\phi/2$ and the number of atoms traversed, and inversely proportional to the fourth power of the velocity of α particles. These are the results experimentally obtained by Rutherford and, as the number of α particles scattered through any angle is also proportional to the magnitude of the positive nucleus charge, he is able to calculate its value. He finds for gold that it is $+100e$, approximately one-half the atomic weight.

If a table of the elements be arranged in ascending order of atomic weight, and numbered consecutively one, two, three, etc., corresponding to hydrogen, helium, lithium, etc., then the atomic number N thus obtained is approximately one-half the atomic weight. The conclusion to be deduced from the experimental evidence is clearly, that the number of electrons per atom, and likewise the magnitude of the positive nuclear charge is the atomic number of the element. Subsequent experimental work has only served to confirm this conclusion. In this connection the work of Moseley should be mentioned. On examining the X-ray spectra of elements used as targets in an X-ray bulb, he found that the square root of the frequencies emitted varied directly as the atomic number. Such a result shows clearly the physical significance of the atomic number, particularly when it is stated that Moseley's results required the inversion in the periodic table of argon and potassium, and of cobalt and nickel. In both cases the chemical

properties agree with the atomic number, not with the atomic weight.

3. It can readily be shown that the mass of the atom resides in the nucleus. From electrolysis the value of e/m for the hydrogen atom is known, and as the charge carried is $e=4.7\times10^{-10}$ *e.s.u.*, the mass is found to be 1.63×10^{-24} gm. Hence, approximately, the ratio of the mass of the nucleus to the mass of the single electron associated with it is $\frac{1.63\times10^{-24}}{8.99\times10^{-28}}=1.84\times10^{3}$. Thus the nucleus is nearly 2,000 times as massive as the electron. From some experiments on the bombardment of hydrogen atoms with α particles, Rutherford[9] has shown that the two nuclei in some cases approach within a perpendicular distance of 2.4×10^{-13} cm. This is less than the diameter of the electron, and indicates a radius for the hydrogen nucleus of probably less than 10^{-13} cm. The density of the nucleus is of the order, therefore, of 10^{15} gm. per c.c. It is, therefore, not unreasonable to assume that the mass of the nucleus is largely electrical.

The nuclei of atoms are very stable structures as no ordinary laboratory experiment is able to affect them in any way. In the disintegration of radio-active substances, however, the nucleus spontaneously ejects with high velocities α and β particles. The rate of this change is not affected by any physical process. Such results indicate not only the enormous forces bound up within the nucleus, but suggest, for the heavier elements at least, that helium nuclei and electrons form part of their nuclear structure. Recent experiments[10] suggest that the nitrogen nucleus is similarly constituted.

Summarizing the above results, a very clear picture of the structure of the atom results. In the centre of the atom is a massive, positive nucleus (radius of order of 10^{-13} cm.), whose charge is determined by the atomic number of the element. About it in a sphere of radius 10^{-8} cm. (the approximate radius of the atom as derived from the kinetic theory of gases) is a group of electrons, whose number is also the atomic number of the element and whose radii are 1.87×10^{-13} cm. The noteworthy feature of this structure is the open-work character of the atom. A very close analogy is to liken it to the solar system. The quantity of

matter in a given volume of space is relatively the same in the two systems. Below are summarized certain important numerical data.

Charge on electron $e=4.7\times10^{-10}$ *e.s.u.* $=1.59\times10^{-20}$ *e.m.u.*
Mass of an electron $m=8.99\times10^{-28}$ gm.
Radius of an electron $=1.87\times10^{-13}$ cm.
Radius of positive nucleus of H atom = less than 10^{-13} cm.
Mass of H atom $=1.66\times10^{-24}$ gm.
Radius of H molecule $=1.21\times10^{-8}$ cm.

Line Spectra

4. Radiation from a body is transmitted to the observer by electromagnetic displacements which travel along Faraday tubes of force. These tubes of force are supposed to radiate from all charged bodies, and to possess the properties of tension independent of length and of mutual repulsion. By means of this conception, as was originally shown by Faraday and later extended by Sir J. J. Thomson, it is possible to explain a great many electrical phenomena. Consider now a moving charge with a number of these tubes of force radiating from it. Those tubes in motion at right angles to their length, by analogy to the motion of a cylinder through a fluid, may be supposed to carry along with them a certain amount of ether, and thus to act as if they had mass or inertia, in addition to their being under tension. Accordingly, a sudden stoppage in the moving charge will not be instantly communicated to the farther parts of the tube, and they will continue to move as they did prior to the stoppage. A kink will then be developed in the tube of force, just as a kink is produced in a stretched rope. This kink will travel out the tube of force with a velocity given by $1/\sqrt{\mu K}$, where μ is the magnetic permeability and K the specific inductive capacity of the medium in which the kink is travelling. If the proper values of μ and K for air are inserted it is found that the velocity $C=2.997\times10^{10}$ cm. per sec. This agrees within the limits of experimental error with the velocity of light in air, and it is for this, and other reasons, that it is believed that light is transmitted by electromagnetic displacements in the ether. There is then emitted from the charged particle when stopped a spherical shell of disturbance travelling out with a

velocity C. If the charge be not stopped, but oscillate about a mean position, then a series of undulations or a train of waves, whose frequency is the number of vibrations made by the particle per second, will travel out along the tubes of force. This in a crude form is the electromagnetic theory of light.[11]

By virtue of the fact that radiation of different frequencies travels with different velocities in transparent media (phenomenon of refraction), or by use of the principle of superposition of trains of waves (phenomena of interference and diffraction), it is possible to analyze a complex radiation into the simple constituent frequencies of the vibrating charged particles. Such analysis is performed by the spectroscope. The resulting spectra are found to be of two main classes: (1) continuous spectra, corresponding to radiation of all possible frequencies and emitted, in general, from solids and liquids under the influence of temperature; and (2) line spectra, corresponding to radiation of a number of discrete frequencies, and emitted, in general, by gases under electrical excitation. In this paper it is proposed to consider only line spectra, and to determine, as far as possible, the conditions of their emission.

5. If line spectra originate in the atoms of a gas, and there is no other reasonable hypothesis, the first problem is to determine what part of the atom—the nucleus or the outer cloud of electrons—is responsible for the radiation. All evidence seems to indicate that it is the vibration of the outer electrons which gives rise to line spectra. The fact that no known variation of experimental conditions can modify the structure of the nucleus, while, on the other hand spectra are peculiarly sensitive to conditions of production, shows very clearly that the nucleus is not the source of radiation. As an example of this are the enhanced lines of various elements which appear, or are strengthened, only when condensed discharges are used.

Further and more direct evidence is given by the Zeeman[12] effect. Repeating an earlier and unsuccessful experiment of Faraday, Zeeman in 1896 placed a sodium flame between the poles of a powerful electromagnet. Examining the flame with a spectroscope of high resolving power he found that, what had previously been a single line was split into three plane-polarized components when examined across the lines of magnetic force, and into two

components, circularly polarized in opposite directions, when examined along the lines of magnetic force. The correct explanation of this effect was suggested by Lorentz. Consider a charged particle vibrating in simple harmonic motion in the flame. Its motion may be resolved into three components—one rectilinear motion parallel to the lines of force, and two circular motions in opposite directions at right angles to the lines of magnetic force. While the magnetic field is off the period of these three components will be the same, and only one line will be seen in the spectroscope. When the field is put on, the period of the rectilinear component is unaffected, but the periods of the two circular components are lengthened and shortened. For the charged particle will tend to move at right angles to its own direction of motion, and at right angles to the direction of the magnetic field. This will cause an expansion of the orbit of one component and a contraction of the other, with consequent effect upon the frequency and hence the wave length of the radiation. Hence, along the lines of magnetic force the observed effects will be obtained—namely, the line split into two components circularly polarized in opposite directions. Across the magnetic field three plane-polarized components will be seen—namely, the two circular motions seen end-on with changed period and therefore changed wave length, and in the centre the rectilinear component with unchanged period and wave length. Further, from an inspection of the direction of polarization of, say, the red component, whether clockwise or counter-clockwise, it is possible to determine if the vibrating change is positive or negative. For a positively charged particle moving in a clockwise direction in a magnetic field will tend to move away from the centre of the orbit, that is decrease the period or increase the wave length. Thus if the particle is positively charged the red component will be polarized in a clockwise direction, and if it is negatively charged the red component will be polarized in a counter-clockwise direction. In all cases it is found that the vibrating particle, which is the source of radiation, is negatively charged. Further, by a very simple extension of this treatment, it may be shown that the value of e/m for this negative particle is given by

$$e/m = \frac{\lambda_e - \lambda_a}{H\lambda_o^2} \cdot 2\pi c$$

where λ_o, λ_c, λ_a are the wave lengths respectively of the original line, of the clockwise circularly polarized component, and of the counter-clockwise component, H is the strength of the magnetic field, and c is the velocity of light. Using the experimentally determined values for these quantities, $e/m = 1.77 \times 10^{-7}$ *e.m.u.* per gm., or the same value as determined for electrons in cathode ray tubes. Thus the Zeeman effect shows directly that it is the vibration of the outer electrons, not the nucleus, which is responsible for radiation.

The preceding discussion of the Zeeman effect has, of course, assumed the electrons to be free from constraint. If the motion be performed under other forces it is clear that the effect would be more complicated. In fact it is found that in the majority of cases the lines are split into more than three components. For example, in the spectrum of molybdenum, the most complicated case yet observed, the lines show 17 to 19 components. This fact does not, however, vitiate the conclusion that it is its electrons which are responsible for the radiation.

6. The second fundamental problem is to determine the nature of the disturbance which sets the electrons in vibration. A study of the phenomena of luminescence shows that it is probably due to one of two things—either the removal of an electron from, or the return of an electron to, the atomic system. The majority of experimental data are equally well explained by either hypothesis, and it is difficult to devise an experiment that will serve as a critical test for the selection of the correct hypothesis. The experiments of H. A. Wilson[13] on the luminosity of flames, however, show very clearly that luminosity is excited only on the return of an electron to the atom. As is well known, when a little sodium chloride, for example, is introduced into a Bunsen flame, the flame not only becomes luminous but the gases composing it are ionized, and it is also attracted to the negative electrode in an electrostatic field. Wilson has repeated these experiments in a very ingenious manner, and has shown that the luminous part of the flame is not deflected in an electrostatic field, while the positive ions are. The introduction of chloroform, which is strongly electronegative and therefore seizes many of the free electrons, reduced the luminosity, though it increased the current carried through the flame. The

only conclusion that can be drawn from these experiments is that the positive ions in the flame are not luminous, nor do they become luminous until recombination takes place—that is, until an electron returns to the atom. A study of certain features of phosphorescence[14] inevitably suggests the same conclusion. For if the phosphorescent substance be cooled the radiation is feeble—*i.e.*, the return of the electrons is delayed, but if the substance be heated, the return of the electrons is accelerated, and there is a sudden, brief blaze of luminescence. The original removal of the electron is probably a photo-electric effect. Still stronger evidence is furnished by the radiation from a hydrogen atom, which consists of a nucleus and a single electron. If it is the removal of the electron from the atom that is the cause of luminescence, then the nucleus must be the radiator. But it has been shown in the previous section that it is the vibration of the electrons which gives the ordinary line spectrum. There is, therefore, no escape from the conclusion that, in general, it is the return of the electron to an atomic system that sets the electrons in vibration and causes radiation.

It can readily be seen, consequent upon the above discussion, that the first condition for the luminosity of a gas is a potential sufficient to ionize that gas—the second condition being, of course, the recombination of the electron and the atom which sets the electrons in vibration and causes radiation. Until the first condition is satisfied, however, radiation is not possible. It is thus easy to account for the fact that, under certain electrical conditions, only the hydrogen spectrum, for example, is seen in a tube containing both hydrogen and helium. For the potential required to ionize a hydrogen atom is only 10.4 volts while 21 volts is required for a helium atom. The striated discharge seen in a vacuum tube is similarly accounted for, when it is remembered that the potential varies periodically along the tube, and it is only when it attains the ionizing potential of the gas that radiation takes place.[15]

7. Having obtained a solution for two fundamental problems in the origin of line spectra there are left three difficulties that must be met by any satisfactory atomic theory. The first difficulty is occasioned by the fact that it is possible to get line spectra at all.[16] For if the inverse square law of attraction holds for atomic dis-

tances, and there is no reason to doubt it, stable equilibrium within the atom can only be secured by the rotation of the electrons in orbits about the nucleus. As the electrons in their orbits radiate, the total energy of the atom changes, and consequently the radii of the orbits and therefore the period of vibration varies continuously. Under such conditions a continuous, not a line spectrum, would be given.

The second difficulty is that there are only a finite number of degrees of freedom within the atomic system. Thus the hydrogen atom with a nucleus and a single electron has only six degrees of freedom, and three of these represent a motion of translation. From such a system one radiation frequency or at the most, if the system be disturbed, three frequencies should be expected. But the hydrogen atom gives a spectrum containing an infinite number of lines—namely, the Balmer series and the secondary spectrum.

The third difficulty has reference to the fact that the lines in the spectra of most elements can be arranged in series.[17] The first relation of this kind was discovered by Balmer, who showed that the wave lengths of the lines in the ordinary "four line" spectrum of hydrogen were connected by the formula

$$\lambda = 3646.14 \frac{m^2}{m^2-4}$$

where m takes the successive integral values 3, 4, 5, . . . As more lines in the hydrogen spectrum were discovered in the chromosphere it was found that Balmer's formula gave a surprisingly close fit. These lines in the hydrogen spectrum have since been known as the Balmer Series. This work was extended by Rydberg, who showed that in the alkali metals there were series of single lines, pairs or triplets, the members of which series were connected by a general formula of the type

$$n = n_\infty - \frac{N}{(m+\mu)^2}$$

where n, the oscillation frequency or wave number, is $10^8/\lambda$ (the number of waves in a centimetre), n_∞ is the oscillation frequency of the limit of the series, N is a universal constant of value 109,675, μ is a series constant, and m takes on integral values. In addition Rydberg pointed out that there were three important types of

series, namely—a Principal, a Diffuse (or 1st subordinate) and a Sharp (or 2nd subordinate) series, the names of which are generally abbreviated to P, D and S respectively. The limit, n_∞, of a series can clearly be expressed in the form $\frac{N}{(m+\mu)^2}$, and Rydberg showed that the P, D and S series could then be represented as follows:—

$$P \text{ series} \quad n = \frac{N}{(1+s)^2} - \frac{N}{(m+p)^2}, \quad m = 1, 2, 3, \ldots$$

$$D \text{ series} \quad n = \frac{N}{(1+p)^2} - \frac{N}{(m+d)^2}, \quad m = 2, 3, 4, \ldots$$

$$S \text{ series} \quad n = \frac{N}{(1+p)^2} - \frac{N}{(m+s)^2}, \quad m = 2, 3, 4 \ldots$$

where p, d and s represent the values of μ respectively in the P, D and S series. These equations show certain important relations between these three types of series. First, that the D and S series have the same limiting frequency. Second, that the difference between the limit of the P series, and the common limit of the D and S series, gives the frequency of the first line in the P series—sometimes known as the Rydberg-Schuster law. Finally, when m is put equal to unity in the S series, the frequency of the first line of the series is obtained with a negative sign. From a consideration of these relations it is clear that, when the positions of lines in two of the P series are known, the positions of the lines in the remaining series may be computed.

That such series represent something physical within the atom, and that a study of them is therefore important in the formation of an atomic theory, will be clear from the following considerations. There is a degradation in the intensity of the lines of the series in passing from the red to the violet. All lines of the one series show the same characteristics—for example, easily self-reversed, or nebulous, or sharp, and all have the same Zeeman and pressure effect. In attempting to fit the metrical relations contained in series into any atomic theory the third difficulty is encountered. Rayleigh[18] has calculated the frequencies of vibrations about a steady state of a cloud of electrons under ordinary electrostatic forces. He finds that it is the square of the frequency, not the

frequency itself, as in series relations, that is obtained. Thus he obtains an expression for the frequencies of the form

$$n \propto 1 - 1/2m$$

where n is the frequency and m takes on integral values. Such an expression is quite different from the series relations discussed above.

A summary of the above discussion makes clear the nature of the problem. Line spectra originate within the atoms of a gas. These atoms consist of a massive positive nucleus surrounded by a finite number of electrons. The electrons act as radiators, and are set in vibration by the return of one of their number to the atomic system. Making use of these facts a successful theory of the origin of espctra must explain the production of a many-lined spectrum, the frequencies of whose lines are connected by series relations. In brief, a theory is required in which the atomic model will give rise to the spectra actually observed.

To be concluded.

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THE MOTION OF THE SOLAR SYSTEM

By F. Henroteau

In the following an attempt is made to determine the motion of the solar system through space with respect to the stationary interstellar calcium clouds.

The problem of the determination of the solar motion is one of the most intricate in astronomy. Its solution has been based mostly on the assumption that all stars have their motions evenly distributed in all directions. However, since Kapteyn's discovery of preferential motions among the stars, coupled with the discovery of star streams such as the Ursa Major stream, and the complications introduced by recognizing the existence of giant and dwarf stars by Russell and Adams, the problem of determining the solar motion with respect to all the stars or certain groups of them seems to baffle an accurate and reliable solution. If we take for instance the two supposed best determinations of the position of the solar apex, the first by Lewis Boss[1] derived from the proper motions of his Preliminary General Catalogue of 6188 Stars which is:

$$\alpha = 270°.5$$
$$\delta = +34°.3;$$

and the second by W. W. Campbell[2] from the radial velocities of 1193 stars which is:

$$\alpha = 268°.5$$
$$\delta = +25°.3;$$

we see that there is considerable difference between the two determinations. Moreover, if we take separate determinations for different spectral types or for different stellar magnitudes we find a considerable range of results. As an example we may give here the different determinations of Dyson and Thackeray[3] obtained from the Groombridge stars for different magnitudes. They are:

[1] *Astron. Journal*, Nos. 612, 614.
[2] *Lick Bulletin*, No. 196.
[3] *Monthly Notices*, vol. LXV., p. 428.

Magnitude	Solar α	Apex δ	Number of Stars
1.0 to 4.9	245°	+16°.0	200
5.0 to 5.9	268°	+27°.0	454
6.0 to 6.9	278°	+33°.0	1,003
7.0 to 7.9	280°	+38°.5	1,239
8.0 to 8.9	272°	+43°.0	811

All the stars which we are considering as points of reference are moving in different directions and perhaps, in the main, rather erratically. Only the *B* stars seem to have rather small velocities and may perhaps be considered as almost at rest in our sidereal universe; however, the *B* stars have, as a rule, exceedingly small parallaxes, they are very distant, hence their determined proper motions must be inaccurate; on the other hand the spectra of *B* stars are usually very poor and the radial velocities which they give have very large probable errors. Besides, we are not justified in supposing that they are devoid of individual motion.

We realize, especially when looking at Barnard's photographs of the Milky Way, or Curtis's photographs of nebulous regions, that there are in space enormous gaseous nebulae. The Orion nebula, the dark lanes in the Milky Way and so on, show that there are in the sidereal universe enormous volumes of gases of several parsecs thickness that we may consider at rest in space. These clouds, of course, are not sharply defined, and are exceedingly distant, so that attempts at measuring their proper motions seem almost futile. From Campbell's researches, as well as from Fabry and Buisson's measures with the interferometer, the average velocity of the Orion nebula is almost zero. Most of these interstellar clouds indicate their existence by the stationary *H* and *K* lines of calcium as was first pointed out by Hartmann—as well as by the stationary D_1 and D_2 lines of sodium, as was shown so beautifully by Miss Heger. These lines are usually very sharp and narrow compared with the other lines of the spectra in which they are found, lines that belong to the elements of the stars; as they are probably the result of absorption of enormous strata of metallic vapours of perhaps several parsecs thickness, their narrowness seems to point out that these clouds are at rest in our universe. Indeed, if they were not at rest it would be difficult to imagine a mass of such huge extent—several parsecs—to have a uniform

motion; it seems more likely that different velocities would prevail, in which case the *H* and *K* lines would be broad and diffuse; however, this is not the case.

Let us then suppose that these interstellar clouds, which are indicated by a stationary *K* line, are completely at rest in space, and we will have fixed points of reference to determine the solar motion. The hypothesis that these clouds are at rest appears better than the one usually adopted in determining the solar motion with respect to stars, that the motions of the stars are distributed evenly in space. The absolute velocities of the clouds being zero, the apparent radial velocities of these clouds given by the stationary *K* lines would be due entirely to the velocity of the sun through space, so that only a very few of these radial velocities would be necessary to give us a good determination of the elements of the solar motion. As a matter of fact, very few spectroscopic binaries with stationary *K* lines have been studied, and in all the data so far published only six were found whose *K* line velocity is constant and fairly well determined. They are given in the following table:

Star	R.A. 1900 h m	Dec., 1900 ° ′	Velocity of *K* line km.	Investigator
Boss 46	0 12 4	+50 53	−23.5	Adams-Strömberg[5]
oPersei	3 38 0	+31 58	+12.5	Jordan[6]
δOrionis	5 26 9	− 0 22	+18.7	Jordan[6]
ρLeonis	10 27 5	+ 9 49	+10.0	Harper[7]
βScorpii	15 59 6	−19 32	−16.6	Duncan[8]
σAquilae	19 34 3	+ 5 10	−12.6	Jordan[6]

All these velocities are obtained, assuming the wave length of the *K* line to be that of Rowland 3933.825.

We shall now determine the elements of the solar motion from the above velocities. We know that if V is the velocity of the sun, D the angular distance of the star from the solar apex, v the radial velocity of the star and K a certain constant error for this velocity, that:

$$V \cos D + K = v \qquad (1).$$

[5] *Astroph. Journ.*, 1918.
[6] *Allegheny Publications*, vols. II. and III.
[7] *Domin. Obs. Publ.*
[8] *Lowell Obs. Publ.*

But if α_0, δ_0 are the equatorial co-ordinates of the solar apex, and α, δ these of the star, we have:

$$\cos D = \sin \delta_0 \sin \delta + \cos \delta_0 \cos \delta \cos (\alpha_0 - \alpha) \quad \ldots\ldots (2),$$

and if we take:

$$\left.\begin{aligned} x &= V \sin \delta_0 \\ y &= V \cos \delta_0 \cos \delta_0 \\ z &= V \sin \alpha_0 \cos \delta_0 \end{aligned}\right\} \quad \ldots\ldots (3)$$

hence:

$$x \sin \delta + y \cos \alpha \cos \delta + z \sin \alpha \cos \delta + K = v \quad \ldots\ldots (4).$$

Having then obtained x, y, z and K from these equations, we shall have:

$$\left.\begin{aligned} V^2 &= x^2 + y^2 + z^2 \\ \tan \alpha_0 &= \frac{z}{y} \\ \sin \delta_0 &= \frac{x}{V} \end{aligned}\right\} \quad \ldots\ldots (5).$$

From the data given above we obtain the following equations of condition:

$$\begin{aligned} +0.776\, x + 0.630\, y + 0.034\, z + K &= -23.5 \\ +0.529\, x + 0.493\, y + 0.690\, z + K &= +12.5 \\ -0.006\, x + 0.144\, y + 0.990\, z + K &= +18.7 \\ +0.170\, x - 0.906\, y + 0.387\, z + K &= +10.0 \\ -0.334\, x - 0.473\, y - 0.815\, z + K &= -16.6 \\ +0.090\, x + 0.398\, y - 0.913\, z + K &= -12.6 \end{aligned} \quad (6)$$

Treating them by a least squares solution they furnish the following normal equations:

$$\begin{aligned} 1.031\, x + 0.789\, y + 0.641\, z + 1.225\, K &= -\ 5.6 \\ 0.789\, x + 1.864\, y + 0.175\, z + 0.286\, K &= -12.1 \\ 0.641\, x + 0.175\, y + 3.105\, z + 0.373\, K &= +55.2 \\ 1.225\, x + 0.286\, y + 0.373\, z + 6.000\, K &= -11.5 \end{aligned} \quad (7)$$

hence

$$\begin{aligned} K &= \ \ 0.74\text{km} \pm \ 3.78\text{-} \\ z &= \ 21.77 \ \ \pm \ 4.77\text{-} \\ y &= -0.36 \ \ \pm \ 7.20\text{-} \\ x &= -19.59 \ \ \pm 11.73\text{-} \end{aligned} \quad (8)$$

and

$$\begin{aligned} v &= -29.3\text{km} \pm 8.6\text{km}. \\ \alpha &= \ 271^\circ \pm 18^\circ \\ \delta &= +\ 42^\circ \pm 40^\circ \\ K &= \ \ 0.74\text{km} \pm 3.78\ \text{km}. \end{aligned} \quad (9)$$

The observed velocities compared with those computed for the *K* line in the above stars are:

Observed	Computed	Residual $O-C$
km.	km.	km.
− 23.5	− 15.5	− 8.0
+ 12.5	+ 5.1	+ 7.4
+ 18.7	+ 22.2	− 3.5
+ 10.0	+ 6.2	+ 3.8
− 16.6	− 10.4	− 6.2
− 12.6	− 21.1	+ 8.5

The method seems to be full of promise, and if some observatory with a large equipment, preferably a large reflector (which does not absorb the violet end of the spectrum), would undertake to measure the stationary *K* lines on large dispersion spectrograms, data would become available for materially increasing the accuracy of the elements of the solar motion.

Dominion Observatory,
Ottawa,
March 31st, 1920.

DEVIATION OF MAGNETIC DECLINATION IN WESTERN CANADA

By W. H. Herbert

The earth itself is a huge magnet surrounded by a magnetic field of which the lines of force extend in curves between the north and south magnetic poles; and any magnetic compass used by an explorer, navigator, etc., is governed by this terrestrial field, but as the magnetic poles do not coincide with the geographic poles, the magnetic compasses do not, except in a very few regions, point to either geographic pole. It follows, therefore, that in each district the magnetic compass needle will point east or west of astronomic north by a different angle. Throughout all regions in which the magnetic compass needle deviates from true north by the same angle a line can be drawn, called an isogonic line or line of equal angle, and by drawing in a series of such lines an isogonic map may be constructed.

The question of irregularities in the isogonic lines, such as bends and loops, has been investigated by many authorities with the unanimous conclusion that such seeming irregularities are the true representation of the actual facts and that smooth and parallel lines generally indicate lack of adequate information.

These irregularities may be explained from the physical standpoint by assuming a certain magneto-motive force applied to the earth, which produces a field governed by the magnetic reluctances of the different geologic strata, mineral occurrences, etc.

From the practical standpoint the irregularities may be divided into two distinct classes: local disturbances and regional disturbances.

Local disturbances may be defined as disturbances existing over a very limited area—generally but a few hundred feet; and are usually caused by a small deposit of magnetic material embedded in a rock of glacial origin. This class is not of much practical importance, and no further consideration will be given to it.

Regional disturbances may be defined as disturbances appreciable over a very considerable area, a hundred miles in many cases; and are usually caused by large deposits of magnetic materials such as iron, nickel and cobalt ores, hydrocarbon deposits, masses of basalt, etc.

Of late years a great deal of time and money has been expended in Western Canada in geologic surveys and prospecting for hydrocarbons and other minerals. When this Branch recently published a new isogonic map for this region, the question at once naturally came up as to what information from a geologic view-point could be deduced from this map. It must be remembered that Western Canada is a very large territory and therefore the geologic information obtained to date is necessarily rather small. Also, in general, geologists and prospectors must confine their work more or less to the surface, as deep borings are very expensive; while magnetic deviations are caused not only by surface deposits but deposits of magnetic material existing very far underground.

It would then seem that a knowledge of magnetic deviations in Western Canada might point the way to localities where geologists and prospectors would stand the best chance of discovering deposits of magnetic materials.

The mere fact that these deviations cannot be correlated with magnetic deposits at the present day does not detract from their value. Indeed, if these deviations could be explained to-day, they would lose all practical value and be relegated to the general fund of scientific knowledge.

In order to measure the magnetic deviation at any point, it was necessary to calculate the theoretical isogonic map and compare it with the actual isogonic map. This was accomplished by making the usual assumption that over the whole territory considered the sum of the westward deviations was equal to the sum of the eastward deviations.

Upon this assumption the declination at any point was expressed as a function of the latitude and longitude of that point by using the second degree equation for the general conic. Solving for the constants by grouping the resulting equations written for points two degrees apart in latitude and longitude, the general empirical equation was obtained from which the theoretical isogonics were deduced.

After a careful comparison with the maps issued by the Geological Survey no relations between the magnetic deviations and the geologic formations could be seen except in the case of the Laurentian formation where intense local disturbances are always apparent.

Sixteen regions where the deviation is two degrees or over follow:—

Portage la Prairie, Manitoba.
Declination 4° below theoretical.

50 Miles N. of Cross Lake, Manitoba.
Declination 2° above theoretical.

Slightly N. of Virden, Manitoba.
Declination 2° above theoretical.

Slightly S. of Swan River, Manitoba.
Declination 3° above theoretical.

25 Miles S.E. Mafeking, Manitoba.
Declination 2° above theoretical.

20 Miles N. Sheho, Saskatchewan.
Declination 2° above theoretical.

North of Amisk Lake, Saskatchewan.
Declination 3° above theoretical.

Northeast of Candle Lake, Saskatchewan.
Declination 2° above theoretical.

Between Saskatoon and Prince Albert, Sask.
Declination 2° above theoretical.

West of Lac la Plonge, Saskatchewan.
Declination 2° above theoretical.

Consort, Alberta.
Declination 2° above theoretical.

75 Miles S. McMurray, Alberta.
Declination 3° above theoretical.

50 Miles S. Lake Claire, Alberta.
Declination 2° above theoretical.

Fort Chipewyan, Alberta.
Declination 5° below theoretical.

Fort Smith, Alberta.
Declination 5° below theoretical.

Between Ashcroft and Lytton, B.C.
Declination 2° above theoretical.

The above discussion is necessarily only a very limited list of some of the more outstanding features on our isogonic map, and indicates to those interested in the subject the possibilities which lie in such a study. A more or less detailed analysis of the whole territory would be extremely voluminous.

TOPOGRAPHICAL SURVEYS, INTERIOR DEPARTMENT,
Ottawa, April, 1920.

MAGNETIC RESULTS, 1918-1919

G. BLANCHARD DODGE

During the season of 1918 some 60 magnetic declination repeat stations were re-occupied, mainly in the southern part of Western Canada, supplying some much needed data as to the secular variation of the declination. The results obtained, considering the number of observers employed, are of a very high degree of accuracy, and show clearly the progressive change in the secular variation across the country. The agreement with the secular variation shown on our magnetic map—Lines of Equal Magnetic Declination and of Equal Annual Change in Western Canada for 1917.0—is also remarkably close. The effect of local attraction at some of the stations is quite noticeable, and for this reason it is necessary to observe at a considerable number of stations in order to eliminate this disturbance. The observations are given below. Dip and Force observations at 27 stations and 22 repeat stations were published in the May-June, 1919, number of this JOURNAL. Some thirteen hundred observations for declination at new stations completed the magnetic work of the season.

During the season of 1919, Dip and Force observations were made at 21 stations, including two stations occupied in 1918 for which the results were but lately available. These stations include five repeat stations, four founded by the Carnegie Institution of Washington and one by the Topographical Surveys. The stations lie mainly to the north and in a region where but little magnetic work was accomplished in the past. The results of observations and deduced secular variations are given below. The observers were G. H. Blanchet, D.L.S.; E. S. Martindale, D.L.S.; and R. C. Purser, D.L.S. A number of repeat stations (not given) were re-occupied for declination measurements only.

All observations for Declination, Dip and Force have been reduced to International Magnetic Standard by direct comparison at the beginning and end of the season with the magnetic standards of the Magnetic Observatory, Agincourt, by courtesy of the Director of the Meteorological Service of Canada. The Declination observations have been reduced to mean-of-month by direct comparison with the continuous declination magnetograms of the Magnetic Observatory of Meanook, Alberta, supplied by the Director of the Meteorological Service of Canada.

DECLINATION REPEAT STATIONS

Place	Long.	Lat.	Date	Dec.	Observer
	° ′	° ′		° ′	
South Junction	95 43	49 01	1910.6	9 30	P. R. A. Belanger
			1918.5	9 14	J. E. Jackson
Berens River	97 02	52 21	1914.8	12 19	A. M. Narraway
			1918.7	12 02	J. E. Jackson
Dufed I	97 43	50 48	1912.6	13 36	G. A. Bennett
			1918.5	13 30	J. E. Jackson
Dufed II	97 43	50 48	1912.6	13 33	G. A. Bennett
			1918.5	13 27	J. E. Jackson
Vannes	97 48	50 50	1913.9	13 46	C. F. Aylsworth
			1918.7	13 28	J. W. Pierce
Woodnorth	101 03	49 47	1914.5	16 09	R. C. Purser
			1918.6	15 58	J. A. S. King
Otthon I	102 28	51 06	1909.7	18 19	J. Francis
			1918.4	18 01	P. M. H. LeBlanc
Otthon II	102 28	51 07	1909.7	18 15	J. Francis
			1918.4	18 00	P. M. H. LeBlanc
Birmingham	102 58	50 57	1910.5	18 19	D. E. Chartrand
			1918.4	17 58	P. M. H. LeBlanc
Tullymet	103 30	51 01	1910.5	18 42	P. A. Carson
			1918.6	18 20	P. M. H. LeBlanc
Balgonie	104 16	50 27	1911.5	18 54	C. Rinfret
			1919.0	18 47	L. E. Fontaine
Edenwold	104 16	50 36	1911.5	18 32	C. Rinfret
			1918.9	18 07	L. E. Fontaine
Pilot Butte	104 23	50 27	1911.5	18 44	C. Rinfret
			1919.0	18 28	L. E. Fontaine
Old Wives	105 55	50 12	1912.6	19 40	C. Rinfret
			1918.7	19 31	C. Rinfret
Macdowall	105 59	52 56	1909.6	24 41	W. R. Reilly
			1918.5	24 18	W. Christie
Clarkboro	106 27	52 19	1910.7	24 23	P. A. Carson
			1918.5	23 42	R. B. McKay
Krydor	107 05	52 46	1915.8	20 55	R. Neelands
			1918.6	20 23	P. J. McGarry
Sonningdale I	107 36	52 24	1914.7	23 52	R. C. Purser
			1918.7	23 30	P. J. McGarry
Sonningdale II	107 36	52 23	1914.7	23 46	R. C. Purser
			1918.7	23 28	P. J. McGarry
Sonningdale III	107 36	52 24	1914.7	23 47	R. C. Purser
			1918.7	23 30	P. J. McGarry
Argo	108 08	52 03	1914.8	23 57	G. A. Bennett
			1918.5	23 40	

DECLINATION REPEAT STATIONS

Place	Long.	Lat.	Date	Dec.	Observer
	° ′	° ′		° ′	R. B. McKay
Battleford	108 20	52 44	1908.7	23 08	Carnegie Inst.
			1918.7	22 58	P. J. McGarry
Claydon	108 59	49 13	1909.7	21 30	C. F. Miles
			1918.5	21 13	G. C. Cowper
Ravenscrag I	109 06	49 33	1911.5	21 31	A. L. Cumming
			1918.4	21 25	G. C. Cowper
Ravenscrag II	109 12	49 35	1911.5	21 36	A. L. Cumming
			1918.5	21 22	G. C. Cowper
Carruthers I	109 14	52 52	1913.6	24 51	A. L. Cumming
			1918.7	24 16	T. A. Davies
Carruthers II	109 14	52 52	1913.6	24 52	A. L. Cumming
			1918.7	24 21	T. A. Davies
Carruthers III	109 15	52 52	1915.6	24 25	R. C. Purser
			1918.7	24 14	T. A. Davies
Moirvale I	109 15	49 28	1912.6	21 47	S. L. Evans
			1918.5	21 44	G. C. Cowper
Carruthers IV	109 17	52 52	1913.6	24 48	A. L. Cumming
			1918.7	24 18	T. A. Davies
Vidora I	109 20	49 21	1914.6	22 02	A. G. Stuart
			1918.5	21 54	G. C. Cowper
Moirvale II	109 20	49 28	1912.6	23 08	S. L. Evans
			1918.5	22 59	G. C. Cowper
Cypress Lake	109 26	49 28	1912.6	22 18	S. L. Evans
			1918.5	22 11	G. C. Cowper
Vidora II	109 27	49 26	1912.6	22 29	S. L. Evans
			1918.5	22 08	G. C. Cowper
Fort Walsh I	109 46	49 33	1912.7	21 59	S. L. Evans
			1918.5	21 49	G. C. Cowper
Fort Walsh II	109 57	49 34	1913.5	21 58	A. M. Narraway
			1918.5	21 55	G. C. Cowper
Lynton	111 05	56 39	1915.8	28 45	E. W. Hubble
			1918.5	28 43	A. E. Glover
McMurray I	111 22	56 44	1911.7	29 48	H. S. Day
			1918.4	29 36	A. E. Glover
St. Paul de Metis	111 22	53 59	1909.7	26 22	H. S. Holcroft
			1918.6	26 05	A. E. Glover
McMurray II	111 24	56 43	1911.6	29 55	H. S. Day
			1918.4	29 34	A. E. Glover
Lavoy I	111 51	53 30	1913.4	26 07	G. W. Coltham
			1918.7	25 45	H. M. R. Soars
Lavoy II	111 52	53 29	1913.5	26 05	G. W. Coltham
			1918.7	25 44	H. M. R. Soars

DECLINATION REPEAT STATIONS

Place	Long.	Lat.	Date	Dec.	Observer
	° ′	° ′		° ′	
McNab I	112 12	49 23	1912.5	23 02	P. B. Street
			1918.5	22 46	J. R. Akins
McNab II	112 14	49 23	1912.5	23 00	P. B. Street
			1918.5	22 46	J. R. Akins
Stonelaw	112 25	51 54	1913.7	24 42	J. B. St. Cyr
			1918.9	24 24	G. A. Bennett
Pincer	113 57	49 31	1911.8	24 47	P. B. Street
			1918.6	25 27	J. R. Akins
Fish Lake	114 00	49 19	1914.6	24 40	M. P. Bridgland
			1918.5	25 44	J. R. Akins
Whitney Creek	114 07	49 23	1910.9	25 41	J. L. Lang
			1918.5	25 06	J. R. Akins
Lyndon Creek I	114 04	50 05	1909.5	24 00	W. A. Scott
			1918.6	24 16	J. R. Akins
Lyndon Creek II	114 05	50 05	1909.5	23 51	W. A. Scott
			1918.6	23 52	J. R. Akins
Lyndon Creek III	114 06	50 05	1909.5	23 55	W. A. Scott
			1918.6	23 56	J. R. Akins
Willow Creek	114 06	50 05	1909.5	24 02	W. A. Scott
			1918.6	24 11	J. R. Akins
Keg River I	117 32	57 44	1916.8	33 05	J. R. Akins
			1918.4	32 43	J. A. Buchanan
Keg River II	117 32	57 44	1916.8	32 58	J. R. Akins
			1918.4	32 42	J. A. Buchanan
Pocahontas	117 55	53 12	1911.5	27 45	G. H. Herriot
			1918.8	27 41	A. E. Glover
Golden	116 57	51 18	1908.5	26 04	Dom. Obsy.
			1918.9	25 49	N. C. Stewart
Jasper	118 04	52 54	1909.7	26 57	J. B. McFarlane
			1918.8	27 14	A. E. Glover
Ashcroft	121 17	50 44	1907.7	27 35	Carnegie Inst.
			1918.6	27 40	W. J. Johnston
Oregon Jack Creek	121 24	50 37	1913.0	26 05	J. A. Calder
			1918.7	25 51	W. J. Johnston
Mundorff	121 27	50 58	1914.8	27 18	C. H. Taggart
			1918.5	27 14	W. J. Johnston

MAGNETIC RESULTS, 1919

Place	Long.	Lat.	Date	Dec.	Dip	H	F	Observer
	° ′	° ′		° ′	° ′	C.G.S.	C.G.S.	
Kamsack	101 56	51 33	July 5/19	16 40	78 45	0.1227	0.6286	R.C.P.
Westasta Valley	104 19	52 16	July 23-27/19	19 12	78 30	0.1245	0.6244	R.C.P.
Twickenham	104 22	52 41	Oct. 17-18/19	19 52	78 30	0.1230	0.6261	R.C.P.
Beauchamp	104 32	52 19	Aug. 16-17/19	19 31	78 28	0.1248	0.6248	R.C.P.
Shady Grove	105 01	52 00	Aug. 8-13/19	19 27	78 06	0.1293	0.6268	R.C.P.
Big River	107 02	53 49	May 18-20/19	23 23	78 50	0.1218	0.6288	G.H.B.
Big Island	107 10	53 57	May 22-29/19	22 49	79 08	0.1184	0.6279	G.H.B.
Wapatuanak	107 43	55 55	Aug. 2/19	25 43	80 11	0.1061	0.6223	G.H.B.
Green Lake	107 47	54 16	Spt. 11-18/19	25 37	79 11	0.1172	0.6245	G.H.B.
Lynx	107 49	55 37	July 26-29/19	26 15	79 45	0.1117	0.6263	G.H.B.
Ile a la Crosse	107 54	55 29	June 19/19 July 7-9/19	25 17	79 44	0.1107	0.6198	G.H.B.
Kisis	108 28	55 51	July 3/19	——	80 00	0.1083	0.6238	G.H.B.
Dillon	108 58	55 55	June 30/19	——	80 02	0.1073	0.6192	G.H.B.
Battle Valley	109 26	53 01	Nov. 5/19	23 55	78 09	0.1275	0.6207	R.C.P.
Evesham	109 50	52 24	Nov. 14/19	24 03	77 15	0.1365	0.6186	R.C.P.
Angle Lake	110 52	53 44	Sept. 25/19	25 35	78 05	0.1283	0.6202	R.C.P.
Athabaska Ldg	113 17	54 42	June 12/19	27 46	77 57	0.1292	0.6187	R.C.P.
Macleod	113 25	49 43	Sept. 11/18	23 45	74 32	0.1621	0.6080	E.S.M.
Edmonton	113 28	53 33	June 17-19/19	27 23	77 25	0.1341	0.6163	R.C.P.
Barrhead	114 23	54 09	Oct. 3/19	27 12	77 32	0.1327	0.6153	R.C.P.
Banff Park	115 34	51 10	July 26/18	26 00	74 56	0.1581	0.6078	E.S.M.

AVERAGE ANNUAL CHANGE

Station	Date	Obs.*	Decl.	Dip	H C.G.S	Date	Obs.*	Decl.	Dip	H C.G.S	Average Annual Change		
											Decl.	Dip	H C.G.S.
			° ′	° ′				° ′	° ′		′	′	
Banff Park	1907.5	C.I.	25 59	74 58	0.1591	1918.5	T.S.	26 00	74 56	0.1581	0.1 E	−0.2	−0.0001
Macleod	1908.8	C.I.	23 37	74 38	0.1634	1918.7	T.S.	23 45	74.32	0.1621	0.8 E	−0.6	−0.0001
Edmonton	1908.8	C.I.	27 21	77 22	0.1362	1919.5	T.S.	27 23	77 25	.1341	0.2 E	+0.3	−0.0002
Athabaska Ldg	1910.4	T.S.	27 59	78 03	0.1287	1919.5	T.S.	27 46	77 57	0.1292	1.4 W	−0.7	+0.0001
Kamsack	1908.7	C.I.	17 02	78 46	0.1239	1919.5	T.S.	16 45	78 45	0.1227	2.0 W	−0.1	−0.0001

*Note.—T.S.—Topographical Surveys; C.I.—Carnegie Institution of Washington. Under "Average Annual Change" of Declination, E. and W. indicate that the needle is moving Eastward or Westward respectively.

The station at Edmonton and Athabaska Landing may be subject to local attraction due to encroachment of buildings.

Topographical Surveys, Department Interior, Ottawa.
February, 1920.

THE FESTIVAL OF THE DEAD

By R. G. Haliburton

(*Continued from page 156*).

Osiris "the Lord of Tombs," is plainly the same as Siva, who "delights in cemeteries, accompanied by ghosts and goblins." He is also designated, like Osiris, "the Lord of the Universe." [13]

In the feast of Lanthorns, or the festival of the dead of the Japanese, and in the November rites of the Fiji deity, we have a clue to the mystic *Isidis Navigium*, to the sacred boat being launched forth into the sea, bearing in it Osiris, the Lord of Tombs; to the sacred bull, Apis, into which the god had entered, being drowned in the Nile; to the annual festival of sending Durga or Kali home to the world of spirits, by casting her image into the Ganges; to the Egyptian and Grecian myth, as to Charon carrying the spirits of the dead across the Styx; to the northern nations of Europe casting "with great solemnity" into a stream, the maypole, which had been ornamented with garlands in honor of the Sclavonian goddess Lada [14]; and to the Roman custom of, almost immediately after the close of the festival of the dead, casting figures of men, made of rushes, into the Tibur.

Can it be possible that the following passage from Tacitus refers only to an accidental coincidence between the customs of the Fijians and of the ancient Germans? The same *dies nefasti*, those unlucky days of rest and peace, when no work could be done, and the same custom of *bathing the God*, characterized this anniversary among both races:—

"In these several tribes there is nothing that merits attention, except that they all agree to worship the goddess Earth, or, as they called her, Herth, whom they consider as the common mother of all. This divinity, according to their notion, interposes in human affairs, and, at times visits the several nations of the globe. A sacred grove on an island in the Northern Ocean is dedicated to her. There stands her sacred chariot, covered by a vestment, to be touched by the priest only. When she takes her seat in this holy vehicle, he becomes immediately conscious of her presence, and in his fit of enthusiasm pursues her progress. The chariot is drawn by cows yoked together. A general festival takes place, and public rejoicings are heard, wherever the goddess directs her way. *No war is thought of; arms are laid aside, and the sword is sheathed. The sweets of peace are known, and then only relished.* At length the same priest declares the goddess satisfied with her visitation, and reconducts her to her sanctuary. *The chariot with the sacred mantle, and if we may believe report, the goddess herself, are purified in a lake.* In this ablution certain slaves officiate and instantly perish in the water. Hence the terrors of super-

[13] The fabled mutilation of Siva, like that of Osiris, gave rise to phallic worship.

[14] Took's View of the Russian Empire, i. 48, ii. 66, 372.

stition are more widely diffused; a religious horror seizes every mind, and all are content in pious ignorance to venerate that awful mystery, which no man can see, and live." [15]

Hence we may infer, that as the goddess was accompanied to the land of spirits by the souls of those who were her ministers and her victims, the traditions that human beings were once thrown into the Ganges, the Nile, and the Tibur, were not, perhaps, without some foundation.

Not only Isis, but Derceto, Ceres and Venus were each represented as annually visiting the sea; and de Rougemont says "On aurait pu tout aussi bien précipiter leurs statues, ou leur images dans les eaux, en commémoration du Déluge." He tells us that the same custom still exists among other races. The Poles, the Silesians, and the Bohemians, to this very day, continue to throw into a river or pool, the image of a woman who bears the name of their ancient goddess the *Earth,* and which has the two names of Ziéwonie or *Life,* and Morena or *Death.* De Rougemont says that the festival Durga takes place, like that of the Sclavonian goddess, in the autumn and the spring, and considers that their festivals are representations of the seasons, *Death* appearing in the autumn and *Life* in the spring.[16] It is evident therefore that when Morena, or Hertha, comes up as Death in the autumn, and is sent home by a baptism in water, to the land of spirits, she is precisely the same as the Fiji god of November. But it is equally plain that this distinction cannot be connected with the seasons, but must be associated with the two divisions of the Pleiades above, and the Pleiades below; because the God of Death is supposed to appear in November in Fiji, where it is a spring month—and November is almost everywhere connected with a festival of the dead, or with the rites of the god of the dead. In Rome, in November, the world of spirits was supposed to be open, *mundus patet,* as it was called.

This took place thrice a year, about the 27th of August, when the Japanese and Chinese festival of the dead takes place, and when the Romans, like the Japanese, had their "lanthorn festival," or a general illumination; on the 3rd [17] of October, about which

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[15] Tacitus, Germ., xl.

[16] Le Peuple Primitif, ii. 253.

[17] It is worthy of remark that the beginning of October, even among races holding the festival of death in November, was also, in some cases, marked by a preliminary festival.

In Egypt, on the 3rd of October, a festival of Isis took place (see Gebelin, iv. 34). Although I supposed, as the yams ripen at the beginning of November, the Inachi of the Friendly Islands was the same as the festival in November in honor of Alo Alo, I find, on a more careful exam-

time the Hindoos held their festival of Durga, and their commemoration of the dead; and in November, at the midnight culmination of the Pleiades.[18]

Riddle gives for this meaning of *mundus* the following explanation:—"A pit dug in the centre of a newly built town, *into which were thrown the firstlings of fruits,* and other things. On three separate days of the year this place was regarded as *the open door of the infernal regions* for the departed spirits to pass through, and was called *mundus patens.*" [19]

These days of rest, which every where characterized not only the great annual commemorations of the dead, but also the monthly festivals in their memory, as well as all those that sprang from this primeval institution, are every where discernible as a connecting link between the customs of nations.

Among the Fijians as well as the ancient Germans and Romans, the anniversary in honor of the dead, or of the god of the dead, was an *unlucky time,* when no war could be declared, and no work done. But as the festival of the dead was a new year's anniversary, the god of the dead became the god of time, or of the year. Hence Pluto is represented as *carrying the keys* of the year, or of the world of spirits, like Janus. The last month of the year was sacred to Pluto, the first month to Janus. They were the embodiments of the same idea, as the German goddess of Life and Death. When Pluto unlocked "the gates of hell," no war could be carried on. But Janus being an auspicious deity, was therefore the God of War, and hence his temple was never closed except in (what the ancients considered an unlucky season) the time of peace. They were both *Janitors* of the year.[20] In the same way the festival of Durga, the Hindoo goddess of Death, marked the beginning of the year. So did that of Carti-

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ination of Mariner's account, that for the Inachi, yams were specially planted a month before the usual time. Hence that festival must have been early in October.

Although Ellis describes the festival of the dead of the Society Islands as "the ripening of the year," on procuring his works, since the foregoing paper was written, I find that it fell when the young canes begin to grow. Whether that is in October or November, I cannot say.

[18] Gebelin, iv. 37, makes it fall on the 7th of November, and Scorpio rise on the 8th; but this occurs at the time of the culmination of the Pleiades at midnight.

[19] Riddle cites the following authorities: Varr. ap. Macrob., 1, 16; Plutarch, Rom., 10, 3. Plutarch shews that in the time of Romulus it took place at the date of the Palilia, the ancient new year's day of Rome, the 21st of April. I have been unable to procure a copy of Macrobius; perhaps the reader may be more fortunate than myself in this respect.

[20] Boulanger (i. p. 160) clearly establishes this connection, though he has not accounted for it. It seems to have escaped the attention of Greswell. See Orig. Kal. Ital., i. 344 to 457.

ceya, the god of the Pleiades. The latter, as I have already shown, was the same as Isis, or Io, and plainly the same deity as Janus. Hence he is the Hindoo God of War, as well as the God of the year.[21]

All the myths, therefore, connected with the festival of the dead, shew that that commemoration and its rites were inherited by all nations from a common source. Even in minute details we have unanswerable proof of this.

The Japanese, at the end of their festival of the dead, "speed the parting guest" by the same means that were in vogue among the ancient Romans at the end of their Lemuria, by casting stones into the air, to frighten home any stray ghosts inclined to linger after the close of the feast of ancestors.[22]

Even the duration of the festival is so similar throughout the world, that this resemblance alone would prove the common origin of the feast of ancestors. It is impossible that accident can have caused the inhabitants of Australia, the Sandwich Islands,[23] Japan, Hindostan, Ceylon, ancient Persia, Egypt, Greece, and Rome, as well as of Northern Europe, to hold this festival for three days.

Captain Cook, struck by the remarkable resemblance between the festivals of the Pacific Islanders, arrived at a conclusion, which may be extended to the whole human race, when he suggested *"the reasonableness of tracing such singularly resembling customs to a common source."*

If all nations have descended from one parent, and have inherited from primeval man this wide spread new year's commemoration of the dead, to what quarter of the globe must we turn for the origin of this festival? If the year of the Pleiades can furnish us with no clue, and the funereal ceremonies of the New Year's festival will supply no guide to this point, yet in the festival of agriculture connected with it, we may be able to learn from what part of the globe it was derived.

In Southern latitudes the new year's festival was accompanied by offerings of first fruits; and these were renewed for a period extending over from two to three months. Traces of a first fruits celebration are to be found in most of the Pacific Islands.

The yams ripen in November in the latitude of the Friendly Islands. Farther north, at the Equator, the first fruits ripen in February, and are offered until June; while in the latitudes of

[21] See Fast. Cath., iv. 64, 69.

[22] See Thunborg's Japan, p. 124; also Boulanger, i. 288. Ovid, Fasti, Lib. v.

[23] See Jarves' Sandwich Islands (Boston, Mass., 1844), p. 37.

Florida[24] and Syria,[25] they ripen in March, and were offered up in that month as part of a new year's celebration.[26]

The Rev. Wm. Chalmers in the Colonial Church Chronicle for 1861 (p. 257), says of the Dayaks of Borneo, "their farming operations are said also to be guided by the constellation of the seven stars (the Pleiades). When it is low in the east at early morning before sunrise, the elders know it is time to cut down the jungle" (*i. e.* June 28th, see p. 256); "when it approaches mid-heaven" (*i. e.*, when it culminates in the morning), "then it is time to burn what they have cut down; when it is declining towards the west, then they plant; and when in the *early evening* it is seen thus declining, then they may reap in safety and in peace" (*i. e. February* 17th, see p. 210).

The harvest, or rather "the feast of Nyiapâan or first fruits, commences on the evening of February 17th, and is kept up at intervals until the great harvest festival on June 9th." This is plainly the same as the first fruits celebration of Alo Alo, in the Friendly Islands, which lasts about 80 days, but commences in November. This festival of first fruits held in February, and regulated by the Pleiades, is important as affording a clue to the mode in which the beginning of the primitive northern year and its festival of agriculture and of death fell, among so many races. in the middle of February.

The same reasons that induced me to suppose that the new year's festival of the Southern year was fixed in November, by the rising of stars (see ante, p. 13), convinced me that Bailly, Greswell and Rodier are in error in supposing the ancient year, commencing in February, was a solar year, and led me to infer that it must have been an *astral* or sidereal year, like that commencing in November. But how it was regulated by the Pleiades I found it difficult to conjecture.

The fact that the first fruits festival commencing in February, is suited to countries near the Equator, proves almost conclusively that the November first fruits celebration must be derived from the far South, where it is adapted to the seasons.

The year of the Pleiades also among the Dayaks is of importance, as a connecting link between the primitive southern and the primitive northern year; and between the systems of regarding the heliacal, and the acronycal rising of the Pleiades, the latter

[24] See Adair's American Indians, p. 109.
[25] See Nelson's Festivals and Fasts of the Church of England, p. 8.
[26] This point is, however, materially affected by the inference that the calendars of nations have changed with the sidereal precession of the Pleiades, a subject to which the concluding portion of these addenda is devoted.

mode, though existing in the southern hemisphere, having for thousands of years become disused among northern nations, and superseded by the former system.

Astronomers have already noticed that the commencement of the oldest year among ancient nations occurred at some time between October and end of February.

Changes have been probably caused by attempts to adapt the November first fruits festival to the seasons which, to races migrating from the south to north, would gradually become later, until a complete revolution of seasons would take place. It is probable that even the year commencing at Yule or Christmas, had its origin far to the south of Europe.

We also find in Borneo a connecting link between the worship of the Pleiades by the Australians, and the traditionary reverence for that constellation in the North. It is called by the Dayaks, "Se Kera from a being who lives there," and who, like Osiris, Ceres, Manco Copac among the Peruvians, and the Great Husbandman of the Chinese, is supposed to have taught mankind the art of agriculture. He is plainly the same as the Fiji god of agriculture, and of death, whose festival took place in November—and reminds us of Proserpine, whose festival of agriculture and of the dead was held in the autumn at the time of the acronycal rising of the Pleiades (see Dupuis, ix., 340). He also recalls to our mind the Egyptian Goddess of Agriculture, Isis, or Io, who was accompanied by the Pleiades in her wanderings over the globe.

Preserving in our All Halloween, All Saints and All Souls, traces of a festival of three days' duration, held in November in Europe, Asia, Africa and Australia, and in some countries plainly connected with and regulated by the Pleiades, or Vergiliæ (the stars of spring), we can scarcely avoid coming to any other conclusion, than that it was once a new year's festival of a year regulated in all latitudes, near November, by the acronycal rising of the Pleiades.[27] But if we admit that, at the beginning of Novem-

[27] These enquiries are based on a comparison of the existing customs of nations, to which previous writers like Boulanger, Gebelin, Dupuis and others have only referred by way of illustration, in their works on the origin of ancient Pagan Mythology. The myths and festivals of antiquity are by me only introduced incidentally, and have been considered less reliable materials, and of a more recent type than the existing observances and rites of the unchanged savage; the Fiji Islander and the Australian being, in an ethnological point of view, more ancient than the builders of the Pyramids.

I have had much pleasure in receiving, since the publication of the foregoing paper, a letter from Mr. Everett, Professor of Mathematics at King's College, Windsor, who has kindly supplied me with such informa-

ber, we have the relics of a primitive new year's celebration, a still more important conclusion is almost inevitable.

We have seen that the universal tradition of our race points to the spring, as a time when the primitive year began. So distinct was the memory of this among some of the northern nations of Europe, that, to express the idea of an annual revolution of time, they adopted the word *"year,"* which originally signified *"the spring."* [28] But nowhere is November a spring month, except far south of the Equator, where at the time of our festival of All Halloween, All Saints and All Souls, the year, regulated by "the stars of spring," is ushered in by an offering of first fruits, and by a commemoration of the dead.

With these facts before us, it is difficult to avoid turning to the Southern hemisphere for a clue to the origin of the festival and of our race.

Such, then, are some of the conclusions to which the study of *Ethology* has led me.

There are, however, further proofs, deducible from chronology and astronomy, which, though less interesting to the general reader, are most important in confirming the inferences to which this inquiry tends. Though they were the last to suggest themselves to me, they will not be, I believe, the least conclusive in the hands of others more competent to deal with them than myself.

If the foregoing paper is imperfect, this is almost unavoidably the case. The field is almost entirely new; and many points were incidentally suggested, while I was preparing the paper; for though collecting materials for a comparison of the customs and festivals of nations required several years of drudgery, many identities in the mode of observing the Festival of the Dead only became apparent to me when I had carefully collated and compared the different references to it, which I had noted in the

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tion as I most required, as to some difficult points that arose in connection with astronomy, a science in which, I must confess, I am but little versed. The following paragraph in the letter will clear up a point that has not, apparently, been distinctly stated in the paper:—

"With respect to the middle paragraph, p. 4, the difference between the aspect of the heavens in the two hemispheres is best brought out thus: Suppose the observer in the northern hemisphere to face that quarter of the heavens in which the sun is at noon, the Pleiades will rise at his left hand; whereas, if an observer in the southern hemisphere faces the quarter in which the sun is at noon, the Pleiades will rise on his right hand. This rule holds strictly for extra-tropical latitudes. In tropical latitudes it is only generally true, that is to say, the sun at noon is for the greater part of the year in the southern quarter of the heavens to an observer in the northern torrid zone; and in the northern quarter to an observer in the south torrid zone. I consider that all your points are well made out."

[28] See Greswell's Fasti Catholici, ii. 109. See ante, p. 40.

course of my reading during the past eight or ten years. Of course, the difficulty of procuring, in a colony, any works bearing on the subject, not a little contributed to my labors.

Before going into what may be regarded as, in some respects, a distinct branch of the subject, it would be as well to recall the steps which have led me so far in this inquiry.

Accident drew my attention to the *antiquity* of certain popular customs; and further inquiry respecting them revealed to me some new facts as to their *universality*.

The simultaneous observance of the festival All Halloween, All Saints and All Souls, in the old and in the new worlds, led me to infer that it must have been regulated by some visible mark or sign that nature had supplied; and on discovering that the midnight culmination of the Pleiades affords a clue to the almost simultaneous observance of this festival in America, Polynesia, Asia, and Europe, I at the same time found that the festival of the dead was a *new year's festival*, and that it, consequently, was in Europe, Asia, and America a vestige of a sidereal (or astral) year, actually in use in the southern hemisphere, but obsolete and forgotten in the north, though forming apparently the substratum of all ancient calendars. My next and last inquiry was, therefore, into the calendars of ancient nations, to see if astronomers have noticed any traces of a primitive system of regulating the year having been once in vogue in different parts of the globe.

Greswell, who has not suspected the existence of the year or seasons of the Pleiades among ancient nations, states that there is conclusive evidence of all calendars having been derived from a primitive calendar. He also states that they were not regulated by or adapted to the tropical year, and that their mutual connection consists in their relation to the 17th day of the Egyptian month of Athyr. This, though probably the primitive new year's day of the Egyptians, became in time the 17th day of the third month, still regulating the year, however; still the *point d'appui* of all calendars; still the basis of all cycles and of all corrections as far back as the year B.C. 1355. The earliest reliable astronomical data which we possess as to the calendar of the Egyptians extend back to that date; and in Hindostan, B.C. 1306 is the limit to which we can safely carry back our calculations.[29]

Greswell shows us that the Egyptian and Hindoo calendars agreed at that remote era; that the festivals of the Egyptian Isis and of the Hindoo Durga were then new year's commemorations; and he even supposes them to have been first instituted, and the worship of these deities to have been invented or introduced, near that time. As, however, we find the rude elements of all the rites

[29] See Fasti Cath., ii. 26; iv. 31.

and attributes of those deities, among the gods, and ceremonies of savages of the Southern Ocean, we may question the correctness of his inference on this point.

This coincidence in the observance of these festivals at that date has naturally appeared so remarkable, that he can only explain it by assuming that they must have had a common origin; and this he finds in the astronomical science of the Egyptians. Although Greswell acknowledges that the existence of a primitive universal calendar is evident throughout the world, he assumes that the Egyptian calendar was the source from which all nations derived their knowledge of the primitive year.

This is plainly most incredible. We must endeavor to find in nature some more simple clue to these remarkable coincidences.

Let us see whether this primitive year, the traces of which have been discerned in almost all countries, was not the year of the Pleiades, or rather the two seasons of "the Pleiades above," and "the Pleiades below."

A careful perusal of his elaborate works will lead to the conclusion, that the four following days stand out with singular prominence as landmarks of this primitive calendar, viz.,—Athyr 17th (November), February 17th, April 20th, and August 28th.

Greswell appears to regard them all as different types of (what is unquestionably the most remarkable of them all) Athyr 17th, as it appeared at different times in a moveable year. But he is evidently mistaken, as I shall hereafter show. All of these days were most conspicuous in the Roman, as well as in some other ancient calendars, and were connected with the primeval festival of the dead, or with the superstitions peculiar to it; while in more modern times we find the new year's festival of the Mexicans, and of the Dayaks of Borneo, fell respectively on November 17th and February 17th, each regulated by the Pleiades; and that on the 19th of February and the 28th of August, among the Chinese and Japanese, the annual commemoration of the dead, or a festival in honor of the new year takes place.

It is however manifest, that each of these four days must have marked a division of the primitive year. But if this was the case, they must have had reference to some natural phenomena or signs; and could not have been merely conventional divisions of the year, as their unequal duration clearly proves; nor could they have been regulated by the seasons, because they are found in different latitudes.

Thus a division commencing on Nov. 17th would contain 92 days; that on Feb. 17th, 62 days; that on April 20th, 130 days, while that on August 28th would not extend over 81 days. Or, supposing that the year was divided into two seasons, the first,

if commencing, like the primitive Southern year, on the 17th November, would last only 154 days, while the second season, commencing April 20th, would continue for 211 days. If, however, it was a year commencing, like the primitive Northern year, on February 17th, the first season must have consisted of 192, and the second season of 173, days.

Such a system is so entirely unsuited to the seasons, and to the natural divisions of the tropical year, that we cannot assume that accident or caprice can have suggested it, much less have preserved such an uniformity, in the observance of such a singular and irregular mode of dividing the year, among nations inhabiting different quarters of the globe.

The solution for all these difficulties will be found, I believe, in the primitive Southern and the primitive Northern years, each of which was sidereal or astral, and regulated by the Pleiades.

I give below a statement of the times of the year, in various parts of the globe, when the Pleiades appear and when they disappear in the evening, also when they culminate at midnight, sunset, or at sunrise.[30]

[30] The following table, kindly prepared for me by Professor Everett, will afford sufficient data to guide the reader as to the variations of the times when the Pleiades appear, disappear, and culminate, at the equator, and in northern and southern latitudes. Of course, the farther we go from the equator, the greater the variations will become:—

	Appearance in evening	Disappearance in evening	Culmination at midnight	Culmination at sunset	Culmination at sunrise
Tongatabu, Friendly Islands, Lat. 21° S.	Nov. 1	April 22	November 17	February 2	August 7
Equator.	Octr. 31	April 28	November 17	February 9	August 14
Hellopolis, Egypt, Lat. 30° N.	Octr. 19	April 30	November 17	February 17	August 21

"These dates," Professor Everett says, "were worked out on a 20-inch celestial globe published in the year 1799. To suit the present time they must all be made a day later. The dates of first and last appearance have been assumed to be those days on which the Pleiades are on the horizon, and the sun is 18° below, an assumption which is only approximate."

Nations regulating their year by these phenomena, without the aid of astronomical science, could only have made an approximation within three or four days of the correct dates. As this is the case, and many of the dates which I have used were adapted to the beginning of the present century, I have, for convenience sake, assumed Professor Everett's table to be applicable to the present time. Most of the dates given by me, it must be remembered, are simply approximations. The ignorance among ancient nations as to the equation of time must also be taken into consideration, in drawing any inferences from the intervals between the festivals observed in November, and in April; more accurate calculation may prove that the second festival of northern nations coincided more nearly with the disappearance of the Pleiades than I have supposed in this paper.

The midnight culmination of the Pleiades occurs all over the world on the 17th of November (or Athyr, as it was called in the Egyptian calendar). Hence if the primitive year was regulated by the midnight culmination of the Pleiades, we may expect to find all affinities in calendars connected with that particular day. This is exactly what Greswell has discovered. He cannot explain why, out of the 365 days of the year, the 17th day of November should be such a *point d'appui* of all calendars. Yet he considers it derived from some primitive unknown calendar, in which it constituted the beginning of the year, and that in all modes of dividing the year, in every portion of the globe, a connection with the 17th of Athyr is to be traced.[31]

With that day, as we have seen, among the Egyptians and Hebrews, the traditions of a deluge were associated. The Mexicans, it is plain, must have connected the same ideas with the very same day, because their great cycle of fifty-two years was regulated by the midnight culmination of the Pleiades, and on the night when that took place, a dread lest the world should then be again destroyed, filled the Aztecs with gloom and dismay, which only passed away, when the Pleiades were seen to reach their highest point in the sky, and a new cycle had begun. To this day the 17th of November is regarded with dread by the Arabs, as well as by the Persians. The very same superstition existed among the ancient Romans, it being by them connected with the rising of Scorpio, which occurs at that time of the year.[32]

Greswell says, referring to the fable of the Pleiades flying from the pursuit of Orion,[33] "in our opinion it was founded ultimately on this Julian year of the Egyptians, in which the stated date of the Epagomenae was Nov. 13, and *that of the first month was Nov.* 18th. Orion and the Pleiades were observed to set always at the same season of the year, and that season November, and within a short distance of each other. In Eudoxus' Calendar (apud Geminum), the Pleiades set cosmically Nov. 14; and Orion begins to set on the same day. According to him, too, Scorpio begins to rise the day before, Nov. 13; and it was another fable of antiquity relating to Orion, that he came to his death by the bite of a scorpion."

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[31] See Fasti Catholici, i. 114, 118; iii. 160, 113, 613.

[32] Calmet says that the months of the primitive Jewish year were in all probability based on those of the Egyptians. Hence we find they have shared in the uncertainty that exists as to the nature of the primitive Egyptian calendar. The primitive Jewish year is supposed to have commenced near the 1st of October.—See Bryant's Mythology, ii. 335. Fasti Cath., ii. 115.

[33] Id., iv. 180.

At the equator, the Pleiades on the 17th of November rise at sunset, and set at sunrise; but this is not strictly the case elsewhere. It is probable that where the new year's festival was fixed by the appearance of the Pleiades at the horizon in the evening (instead of by their midnight culmination), which would occur some time before the 17th November, we shall find the festival falling at the end of October or the beginning of November. In Japan a festival called Matsuri, *of three days duration*, falls on the 18th, 19th, and 20th of October, *i. e.* at the time of the first appearance of the Pleiades in the evening—(see Professor Everett's table, p. 58).

A study of the stars that are visible in the middle of November will, I believe, throw a new light on the strange tradition referred to by Virgil, and which has excited so much speculation—

"Candidus auratis aperit cum cornibus annum
Taurus."

This has, by all writers, been supposed to refer to a very remote period, when the sun was in the sign of Taurus, at the time of the vernal equinox. It has been assumed that the primitive year began at the time of the vernal equinox, and was a solar year.

I think it is very apparent, from the facts referred to in the foregoing paper, that the most ancient year began in the autumn, and that there is not the slightest trace of any ancient year in general use beginning in May. How, then, can we connect this tradition with the evidence of ancient calendars, pointing to November, not to May, as the month in which the primitive year began?

It is manifest that this universal tradition, that is so discernible to this day in the religious symbols and rites of Asiatic nations, and which was so conspicuous in the mythology of the Egyptians, had reference not to a solar, but to a sidereal year; not to the sun being in the *sign* of Taurus, but to the stars in Taurus, the Pleiades, which by their rising in the evening, culminating at midnight, and setting in the morning, marked the beginning of the primitive year in November. The reader has only to consult the various writers who have touched on this point, and he will find that there can be but little question as to the correctness of this view of the tradition. I have already connected Io with the year of the Pleiades, accompanied as she was by those stars in her wandering over the globe.[34] But I omitted to note a feature in the story of Io, which confirms this conjecture. Why was she represented as having been changed into a *Cow*, and as having in that form arrived in Egypt, where she was worshipped as Isis, to whom the bull Apis was sacred, as well as to Osiris?

[34] Manners and Customs of Ancient Egyptians (ed. 1834), i. 300.

 To be Continued.

NOTES FROM THE METEOROLOGICAL SERVICE

MAY, 1920

TEMPERATURE

The mean temperature was below the normal in British Columbia, Alberta, most of Southern Ontario, and in the greater portion of Nova Scotia, elsewhere it was average or above. The most pronounced negative departures occurred in British Columbia, amounting in some places to 5°. The positive departures were not pronounced, nowhere exceeding 3°.

PRECIPITATION

The precipitation was below the average in all portions of the Dominion, except over a portion of British Columbia and a few scattered places in Alberta and Saskatchewan, and on the Island of Anticosti. From Ontario to the Maritime Provinces the negative departure was very pronounced, varying from an inch to two and three-quarter inches. The total fall in many parts of Ontario was less than half-an-inch, in Western Quebec less than an inch, and over large sections of the Maritime Provinces barely over an inch. At Toronto, where the rainfall has been recorded since 1840, it was the driest May experienced.

TEMPERATURE FOR MAY, 1920

STATIONS	MAY		STATIONS	MAY	
	Highest	Lowest		Highest	Lowest
Yukon			*Western Provinces–con*		
Dawson	78	12	Qu'Appelle	77	28
British Columbia			Regina	—	—
Atlin	—	—	Saskatoon	—	—
Agassiz	84	30	Souris	—	—
Barkerville	58	19	Swift Current	80	30
Kamloops	84	32	Winnipeg	82	22
New Westminster	81	35	*Ontario*		
Prince Rupert	62	36	Agincourt	86	29
Vancouver	77	35	Aurora	60	15
Victoria	67	40	Bancroft	85	21
Western Provinces			Barrie	84	30
Battleford	83	27	Beatrice	82	23
Calgary	76	26	Bloomfield	79	32
Edmonton	79	29	Brantford	—	—
Medicine Hat	87	31	Chapieau	78	24
Minnedosa	80	25	Chatham	86	30
Moosejaw	80	30	Clinton	80	23
Oakbank	79	24	Collingwood	84	30
Portage la Prairie	79	26	Cottam	79	30
Prince Albert	84	23	Georgetown	85	28

TEMPERATURE FOR MAY, 1920—*continued*

STATIONS	MAY		STATIONS	MAY	
	Highest	Lowest		Highest	Lowest
Ontario—continued			*Ontario—continued*		
Goderich	—	—	Southampton	76	27
Gravenhurst	83	31	Stonecliffe	90	20
Grimsby	86	31	Stoney Creek	84	31
Guelph	—	—	Toronto	83	31
Haliburton	87	23	Uxbridge	84	29
Huntsville	82	25	Wallaceburg	78	29
Kenora	78	26	Welland	85	29
Kinmount	—	—	White River	80	19
Kingston	73	24	*Quebec*		
Kitchener	80	28	Brome	82	22
London	85	26	Father Point	69	28
Lucknow	82	19	Montreal	83	35
Markdale	—	—	Quebec	83	29
North Gower	84	25	Sherbrooke	83	30
Oshawa	61	30	*Maritime Provinces*		
Ottawa	84	32	Charlottetown	76	28
Paris	85	29	Chatham	84	28
Parry Sound	78	28	Dalhousie	—	—
Peterborough	85	30	Fredericton	83	25
Port Arthur	71	27	Halifax	74	28
Port Burwell	78	29	Moncton	—	—
Port Dover	82	28	St. John	74	30
Port Stanley	74	26	Sussex	80	23
Queensborough	81	29	Sydney	76	26
Ronville	82	28	Yarmouth	72	28

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH, TORONTO

SIR FREDERIC STUPART, F.R.S.C., ,DIRECTOR

P.T. = Preliminary Tremors. S. = Secondary Waves. L. = Large Waves. A.C. = Air Currents. Time is Greenwich Mean Civil Time. 0 or 24 h = midnight.

No.	Date 1920	P. T. Comm.	S Comm.	L. W. Comm.	Max	End	Max Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
2141	May 7			6 50.5)	7 08.4	7?44.7	0.3	
				6 58.7)				
	" 7	Record	of quake	lost, paper not being paid out.				
2142	" 8			21 33.8	21 35.0	21 47.9	0.1	
2143	" 8			23 20.9)			0.05	
				23 35.9)				
2144	" 9			8 31.1	——	——	0.1	
2145	" 10	19?11.4	19?18.3	19 22.8)	19 32.0	——	0.3	L 19 49.8.
				19 28.9)				
2146	" 10			20 03.6	20 05.6)	20 36.4	0.4	eL 20 16.9.
					22 20.0)		0.5	
2147	" 12		2?20.6	2 26.9)	3 09.3		2.8	Times of early phases doubtful. Repeat L 3 58.7
				2 44.9)				
2148	" 14			18?31.3			0.05	
2149	" 19			13 39.4)			0.1	
				13 52.5)				
2150	" 20		7?56.4	8 27.7)	8 40.0	9 58.0	0.5	Repeat L 9 36.4.
				8 37.9)				
2151	" 21			17 36.2)			0.2	May not be seismic.
				17 51.6)				
2152	" 22			17 13.1	17 15.3	17 20.3	0.2	
2153	" 26			13 17.6	13 21.6	13?48.1	0.3	Thickening.
2154	" 30			21 04.3)			0.1	Micros going on.
				21?18.1)				

Period of Boom 18 seconds. Pillar inclination 1 mm = 0″.45.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH, VICTORIA B.C.,

F. NAPIER DENISON, SUPERINTENDENT

No.	Date 1920	P. T. Comm.	S Comm.	L. W. Comm.	Max	End	Max Amp.	Remarks
		h m s	h m s	h m s	h m s	h m s	mm.	
2138	May 7	5?56 09	6 05 01	6 17 18	6 32 03	8 18 47	0.5	7440 km.
2139	" 7	21 53 43	22 00 37	22 10 57	22 18 49	0 47 49	0.3	Very clear record 5230 km Repeat L23 51 07.
2140	" 8	21 06 33			21 11 58	21 23 16	0.2	
2141	" 8	23 20 19			23 21 48	23 25 14	0.1	Probably a quake.
2142	" 9	8 39 32			8 44 56	8 51 49	0.2	
2143	" 10	19 12 05	19 20 16	19 32 14 } 19 41 04 }	19 43 33	21 13 33	0.9	6840 km.
2144	" 13	2 13 13	2 19 07	2 29 56	2 37 18	4 39 01	3.0	Repeat L4 09 50 4120 km.
2145	" 14	18 23 51			18 26 20	18 38 44	0.2	
2146	" 19	13 33 51			13 38 17		0.1	P may be L phase.
2147	" 20	7 39 09	7 49 04	8 01 57	8 12 52	10 21 13	0.5	8700 km. May be near Guam.
2148	" 22			17 42 21	17 48 48	17 58 13	0.5	
2149	" 26	12 44 45		12 57 04	13 02 00	13 26 55	0.5	P may be S phase.
2150	" 27				6?21 14		0.05	May be due to light variation.
2151	" 30	20 58 53		21 02 50	21 04 48	?	0.4	

Period of boom 18 seconds. Pillar inclination 1 mm =0."54.

BOOK REVIEWS

The Amateur's Telescope. By Rev. Wm. F. A. Ellison, M.A., B.D., F.R.A.S., F.R.Met. Soc., Director of Armagh Observatory. 112 pages, 4½ x 7 inches. Belfast: R. Caswell and Son. 1920. Price, 10 shillings.

It is a pleasure in reading a book to feel that the author is a real master of his subject and that he writes out of the fulness of his experience and his enthusiasm for his work. Such is the case here.

The book is intended to explain how the amateur can construct his own telescope, and it is largely a reprint of articles which appeared in the *English Mechanic* during 1918. Mr. Ellison states that his first telescope was constructed when he was only ten years old. It consisted of a spectacle lens, a sixpenny microscope, and a pasteboard tube; and with this humble instrument he first viewed Jupiter's satellites, the phases of Venus and the lunar mountains. Since then he has made 70 mirrors ranging from 6 to 12 inches in diameter, and achromatic objectives up to 5¼ inches aperture.

The entire process of producing mirrors and lenses, from the obtaining of the glass discs to the completed article, together with methods of testing and mounting, is described in detail. The author also gives a multitude of practical suggestions, the value of which he has demonstrated in his years of experimenting. In the course of the work on his numerous mirrors he made many variations upon the instructions given by previous writers, often with advantage and never producing any serious results.

The book can be highly recommended to those "handy" persons who like to make their own instruments. Indeed in this class there have been many distinguished men, for instance, Herschel, Clark and Brashear, who began as amateurs but soon

attained world-wide eminence. Who knows but that this little book may start someone on the road to equal distinction?

Die Veränderlichen Sterne; die Berchnung der Beobactungen. Von J. G. Hagen, S.J., Direktor der Vatikan-Sternwarte. Freiburg im Breisgau, Herdersche Verlagsbuchandlung, 1920.

This is the third section of the first volume of Father Hagen's authoritative treatise on variable stars. It contains pages 333 to 518, of quarto size. The first section appeared in 1913, the second in 1914, and the fourth and last one of this volume is in press. A second volume will conclude the work. The paper and printing are superior and the work will undoubtedly be the standard for many years.

Temperature Variations in the North Atlantic Ocean and in the Atmosphere. By Björn Helland-Hansen and Fridtjof Nansen. 408 pages and 48 plates. 6¼ x 9¾ in. Washington: Smithsonian Miscellaneous Collections, vol. 70, No. 4, 1920. (Translated from the Norwegian).

This is a notable contribution to the literature of meteorology. An attempt is made to analyse the almost numberless meteorological records and to deduce some laws from them. A considerable portion deals with the relation of solar conditions to meteorological phenomena.

C. A. CHANT.

ASTRONOMICAL NOTES

NEWS ABOUT NEW STARS

Announcement which has just come in from the Lick Observatory throws a very interesting light upon the complex but fascinating problem of the "new" or temporary stars.

It has been known for about twenty years that these strange bodies, as they go through their rapid changes, follow a fairly definite law. The original outburst is extraordinarily rapid, and brings the star from a faint telescopic object—sometimes indeed from invisibility—up to many thousand times its original brightness within a couple of days. This great brilliancy is almost as short-lived as the increase in light, and there follows a steady fall in brightness broken by irregular fluctuations, so that at the end of a year the object emits perhaps one per cent. of its maximum light, while in a decade it has fallen almost to its original luminosity. As these changes in light go on, the spectrum undergoes equally remarkable variations. The few observations that have been made during the increase of brightness show a spectrum of the ordinary type, crossed by dark lines—which, however, are much displaced from their normal position. Just as the maximum light is reached the spectrum changes into a flaring affair, full of bright bands, flanked by dark lines on the side of shorter wave-length, toward the violet. The lines of hydrogen are most conspicuous, but helium is also present, and other bands can be identified with "enhanced" lines of some of the metals—that is, lines which are produced in the laboratory when the metallic vapour is very strongly excited to luminosity by a powerful electric spark. Later on, as the light begins to fade, the characteristic nebular lines in the green and violet make their appearance, and become the most conspicuous feature of the spectrum, while the other lines fade away. At a still later stage the spectrum resembles that of the nucleus of a "planetary" nebula, or of one of the Wolf-Rayet stars which are found here and there in the Milky Way.

What We Read in the Spectroscope

Half a dozen different novæ have exhibited essentially this same spectroscopic behaviour, with minor differences from star to star, and it is evident that the strange sequence of changes represents a pretty definite physical process—but what can this process be? Probably the easiest evidence to interpret is that furnished by the widening and displacement of the lines in the spectrum. The bright bands, though enormously widened, are not greatly shifted in position—

that is, they spread out on each side of the usual position of the line, toward both the red and the violet, so that the centre of the line occupies substantially its normal position. The dark lines, on the contrary, are all enormously shifted toward the violet—so far, indeed, that it is not an easy matter to identify them at all. Those which correspond to the bright bands lie exactly at the edges of the latter, on the side toward the violet.

The widths of the bright bands, and the displacements of the dark lines, which are evidently just one-half as great, are greatest in the red and least in the violet parts of the spectrum—being, in fact, proportional to the wave-lengths of the lines. This is the characteristic effect produced by motion in the line of sight, and not at all similar to the influence of pressure, which widens and shifts different lines by irregularly varying amounts.

But if the behaviour of the lines is due to motion of the gases which produce them, why should the bright bands be greatly widened, and not shifted bodily, while the dark lines are shifted, and much less widened?

The explanation is found in the bold hypothesis that the star is surrounded by a shell of incandescent gases, ejected from it at the time of the outbreak, and expanding in all directions. The absorption lines will be produced by the part of this shell which lies between us and the star. Here the gases will be moving toward us—hence the lines will be shifted toward the violet. The bright emission lines, however, will be given out by all parts of the expanding shell. The light from the nearer side, which is approaching us, will give lines shifted toward the violet; that from the farther side, which is receding, will exhibit an equal shift toward the red; while the light from that part of the shell which is moving at right angles to the line of sight will give undisplaced lines. Other parts of the shell will give lines displaced to all intermediate degrees, and the combined effect of the whole will be to produce a wide, diffused spectral band, with its centre at the normal position, and extending equally far to the red and to the violet. Since the gas which produces the absorption lines is moving directly toward us, these will be displaced by the maximum amount, and will fall just at the edge of the bright bands.

A Monumental Velocity

No other simple hypothesis seems capable of accounting for the phenomena, and we have the high authority of Professor Adams for believing that this is the real explanation. The difficulty about it is the enormous magnitude of the velocity of expansion which is necessary in order to account for the facts. In the case of Nova Aquilæ of 1918, the hydrogen, helium and nebular lines were broadened and displaced for months continuously, to an extent which for explanation demanded a shell expanding with a velocity of 1,250 kilometers per second. Certain dark lines which appeared for a short time during the earlier history of the Nova indicated velocities even greater.

Now at this rate the expanding shell of gas would reach a diameter equal to that of Neptune's orbit in six weeks, and at the end of a year would be 24 billion miles across—260 times as large as the earth's orbit. Are such velocities

credible? and, if they really exist, ought we not to see the luminous shell of gas as a disk of light—a little nebula?

It is to this question that the observations at the Lick have given a remarkable and decisive answer. Within four months after the appearance of the Nova, Barnard at the Yerkes Observatory noticed that it appeared in the great telescope not as a point, but as a small greenish disk, about a second of arc in diameter. Aitken, at the Lick Observatory, in September, 1919, observed this disk again, and found it 2.4″ in diamteer, and conspicuously bluish-green. Photographs of the spectrum showed that the light of the disk came mainly from the nebular lines, which explained the colour. A recent telegram states that Moore and Aitken, on June 9th of this year, found the disk to be 3.8″ in diameter. Putting these values against the time, it is found that the diameter of the disk is proportional to the time elapsed since the outburst of the Nova.

The Telescope Verifies the Tale

In other words, Nova Aquilæ is surrounded by a small gaseous nebula, which is expanding steadily at a uniform rate, and which apparently originated at the time of the great cataclysm. No more direct or more beautiful confirmation of Adams' hypothesis of the expanding shell could be imagined. The thing is there, visible in the telescope, and expanding in all directions before our eyes.

If we assume that the rate of expansion, in kilometers per second, is the same as that indicated by the width of the bands in the spectrum, it follows that the diameter of the nebula at present, two years after the outburst, is slightly more than 1,000 times the earth's distance from the sun. This would make the distance of the Nova about 900 light-years. Its brightness before the outbreak would then come out about twice that of the sun—a very ordinary dwarf star; while at maximum its luminosity appears to have reached the extraordinary amount of 150,000 times the sun's light. This is a startling figure; but the estimate of distance which we have just made is supported by the smallness of the proper motion of the nebula—only 0.018″ per year, which would correspond, at the assumed distance, to 24 kilometers per second, a very ordinary rate of stellar motion.

What causes a star, which has previously shown no peculiarities to speak of, suddenly to burst out into such enormous brightness, and to eject nebulous gases in all directions with prodigious speeds, we are as yet quite unable to determine. It may be the result of a collision, or of some sort of internal explosion within the star. We can be sure of one thing at least. These phenomena, which occur somewhere in the Milky Way fully as often as once a year, involve by far the most tremendous catastrophes of which the human race has at present any knowledge.

Perhaps the most impressive thought of all is that if our present estimate is sound, the catastrophe which we saw and recorded, here on earth, on the night after the eclipse two years ago, actually happened in the eleventh century of our era, long before William the Conqueror set foot in England.

—Prof. H. N. Russell in *Scientific American.*

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

FOCUS OF AURORAL STREAMERS

Further evidence regarding the nature of the auroral streamers and their relation to the earth's magnetism is given by Prof. Joel Stebbins in *Science* for May 14, 1920. He and his assistant, Mr. C. C. Wylie, at Urbana, Ill., made 14 separate observations of the position of the focus of the streamers during the great display of March 22, and the mean of all the estimates differs only 0°.7 from the position of the magnetic zenith as determined by the Coast and Geodetic Survey in 1917.

As is well known it is believed that the streamers are in straight lines parallel to the magnetic lines of force of the earth, and that their apparent meeting-place (an effect of perspective) is that point in space to which the dipping needle directs itself. These observations strongly support this view.

It may be remarked, also, that at the time of this display there was a huge group of spots almost central on the sun. It had begun to pass the centre about two days before. When the sun had completed a rotation on April 16 a medium sized spot became central, and on the 17th there were magnetic disturbances as well as an auroral display (see page 211 of last issue).

C. A. C.

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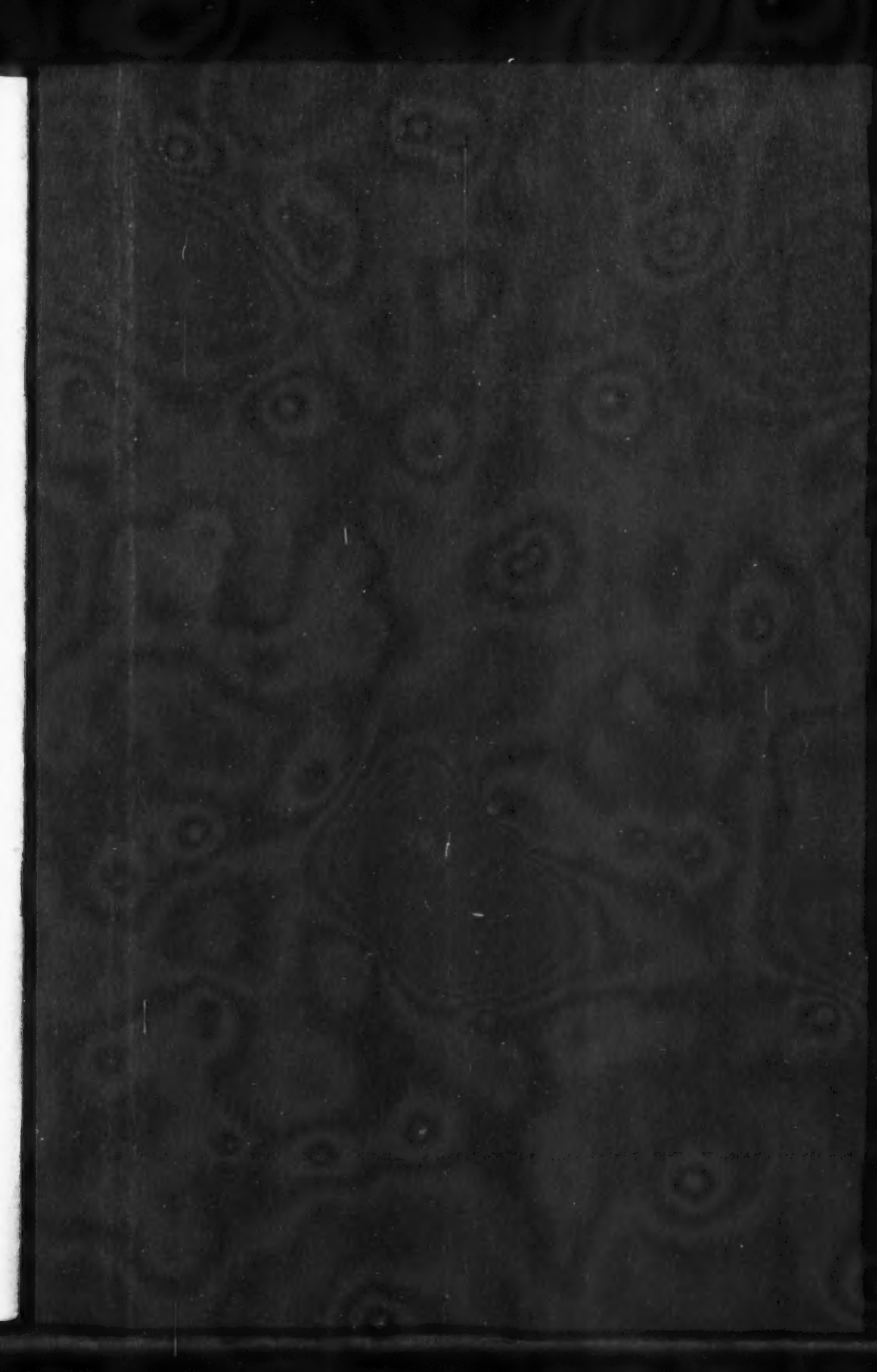
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